LBNL-58634

Best Practices for Energy Efficient Cleanrooms: Cooling Tower and Condenser Water Optimization

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June 15, 2005

The project is funded by the California Energy Commission's Industrial section of the Public Interest Energy Research (PIER) program (http://www.energy.ca.gov/). This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

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Summary

Cleanroom energy benchmarking data shows that chiller plant designs and operation efficiency varied a great deal in cleanroom facilities. Operating efficiency of cooling tower and condenser optimization is critical to the overall energy efficiency of the chiller plant, which has a significant impact on energy use for such facilities.

Together with fans for delivering air to and from cleanrooms, chiller plants usually serve cleanroom facility and adjacent spaces simultaneously and use significant energy and water. Figure 1 shows benchmarked HVAC energy usages in a semiconductor cleanroom facility. In this case, the cooling towers, water pumps, and chillers account for more than half of the total HVAC energy use. Therefore, it is important to design, select, operate, and control each of the plant components to achieve high efficiency and to lower life-cycle costs for cleanrooms and their adjacent spaces.

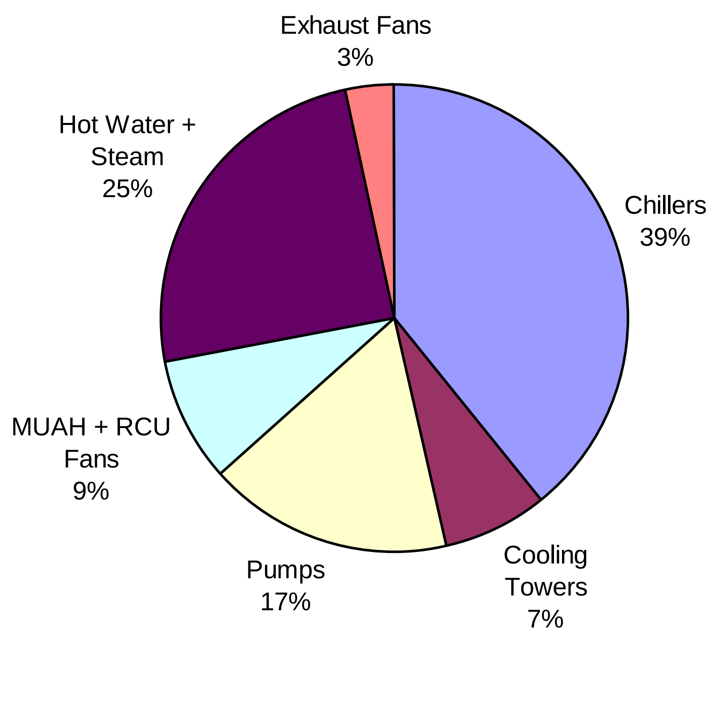

Figure 1. Benchmarked HVAC energy usages in a semiconductor cleanroom facility

Principles

The efficiency level of overall chiller plant is influenced by the efficiency of individual components and subsystems in the plant. Major components include chillers, primary loop chilled water pumps, secondary loop chilled water pumps, condenser water pumps, and cooling towers when feasible. While nominal energy efficiency ratings of individual component influence the overall chiller plant efficiency, how a cooling tower and a condenser system is designed, controlled, and operated also largely determines the actual system efficiency.

Proper design and operation of a condenser water system can greatly affect its energy use and life-cycle costs. Optimizing the design and operation requires a good understanding of how the system components affect each other.

A cooling tower can efficiently remove heat from the condenser water through heat transfer to the surrounding air. Sizing of a cooling tower is defined as its capability of cooling a certain flowrate of water with a temperature drop under design wet-bulb conditions. Proper sizing and control of cooling towers is however critical to efficient chiller plant operation. Normally a higher design wet-bulb air temperature would require a higher air flowrate to remove the same amount of heat; therefore, a larger tower will be needed.

When chillers operate at a higher condenser water supply temperature, a larger temperature differential of chilled water would cause the chiller to use more electric power to achieve same amount cooling. Therefore, decreasing condenser water supply temperatures can improve the chiller plant efficiency.

Best practice approaches

Full understanding of the local climatic condition (i.e., web-bulb temperature) is essential for evaluating the load and the feasibility of installing cooling towers. The following lists important best practice approaches that the design and operation teams should undertake:

- Avoid under-sizing the cooling tower
    - Over-size the cooling tower when it is practical
    - Consider propeller or axial fans in the cooling tower
- Integrate controls of water temperatures, fan, pump, and chiller

Normally, for centrifugal compressor-based chillers, a decrease of one degree in the condenser water temperature can normally improve the full-load operation energy efficiency of the chiller by almost one percent. If chiller condenser water is at 60°F, the system will be 15 to 20 percent more efficient than when its condenser water temperature is at 80°F. Therefore, a best practice approach is to examine the applicably lowest condenser water supply temperature and thus lower the condenser water supply temperature to the chillers.

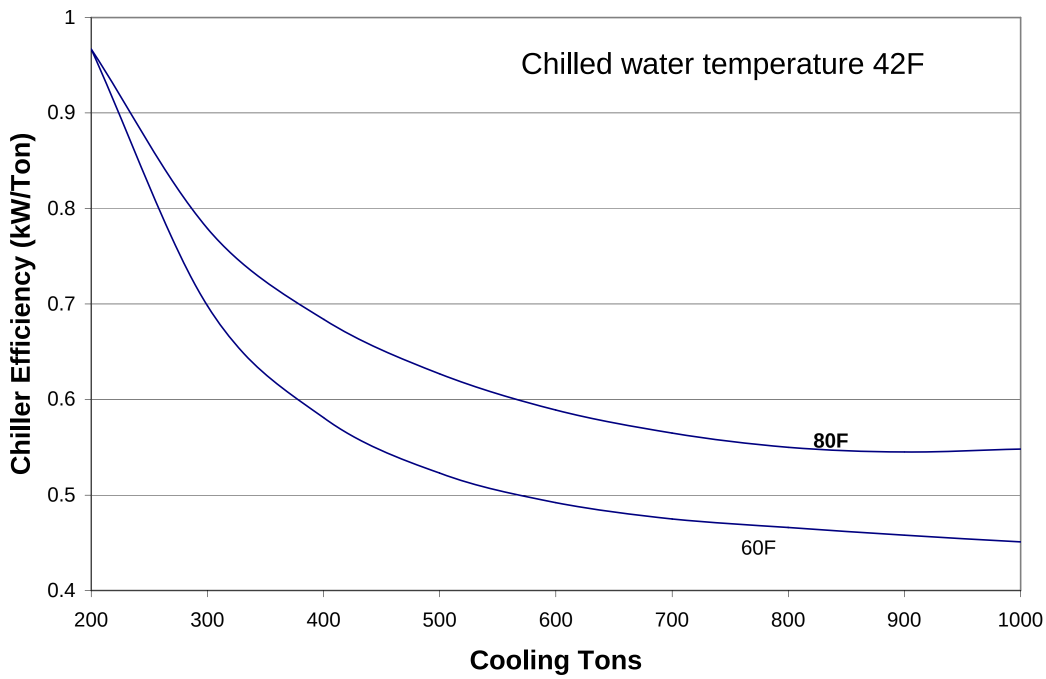

Figure 1. Cooling tower

Case studies

Figure 2 shows the variations in cooling tower efficiency for a group of cleanroom facilities. The cooling tower best practice efficiency based upon energy benchmarking and on-site observation was 0.013 kW/ton. In one of the facilities studied, for example, chillers were supplied with condenser water at an average temperature of 74°F, while typical chillers can accept a minimum of 55°F to 60°F condenser water supply. If a chiller can operate with 60°F entering condenser water temperature, it will be 15 to 20 percent more efficient than when it receives the warmer 74°F water. In this regard, the best practice in design phase is to select a chiller that could operate at reduced condenser water temperature.

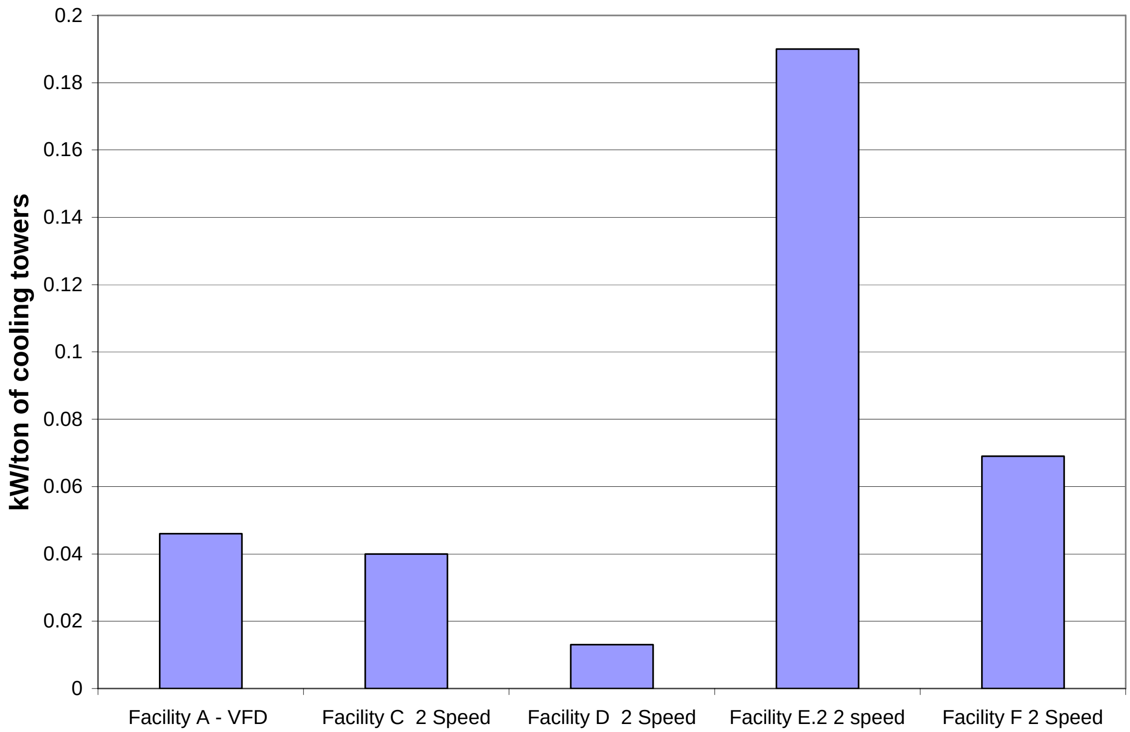

Figure 2. Cooling tower efficiency

Related best practice

- Right sizing
- Control of chilled water system
- Variable speed chillers including chiller efficiency
- Variable speed pumping
- Free cooling
- Dual temperature cooling loops

References and resources

1) http://hightech.lbl.gov

2) Energy Design Resources, Design Brief: Chiller Plant Efficiency, http://www.energydesignresources.com/resource/24/

3) ASHRAE handbook – HVAC systems and equipments. Chapters 13 and 36

4) PG&E's CoolTools, http://www.hvacexchange.com/cooltools/